Author - Industry Canada Publication Date - 2000-03-29

The views expressed in this occasional paper do not necessarily reflect those of Industry Canada or the federal government

Productivity and Sustainable Development: Micro Fundamentals.

Philippe Crabbé,1
Institute for Research on Environment and Economy,
University of Ottawa

Abstract

Sustainable Development (SD) and Neo-Classical Economics (NCE) provide different but overlapping perspectives on how society may address economic, environmental and social challenges. While NCE is at a relatively mature state of conceptual development, SD is still at the early formative stages. A key focus of SD is equity, while that of NCE is efficiency. Empirical evidence shows a decoupling between real income per capita, a mean which is the main NCE concern, and well-being,an end which is the main SD concern. NCE aims at maximizing GDP per capita, a flow, while SD focuses on the value of capital including amenities and opportunities, a more long-term goal. However, both NCE and SD are interested in increasing total factor productivity. SD acknowledges natural capital as the scarce factor of production and emphasizes eco-efficiency and a shift from non-renewable resources to renewables, while knowledge is the scarce factor for NCE.

The new industrial changes needed to advance SD will require increasing the rate of natural-capital saving (mission-oriented) innovations and services. While efficiency is often not an explicit part of the SD agenda, increasing the scarcity of natural capital, the assumed widespread availability of no-regrets solutions, and capital-saving innovations improve overall economic efficiency. SD emphasizes the systemic complementarity among the four forms of capital (e.g. in closing material, and production and product liability loops) while NCE moves in that direction (e.g. recent emphasis on social capital) except for natural capital. NCE is market-based while SD calls for both top-down public sector involvement and bottom-up approaches. NCE favours regulatory, competition, and intellectual property rights reforms. SD currently appears to favour such top down mechanisms as voluntary environmental instruments (e.g. covenants), the Porter Hypothesis, eco-taxation, and education; and at the same time favour such bottom-up instruments as procurement, user groups concertation, and eco-labelling and ISO 14,000 whose norms require government

sanction. The NCE goal of developing knowledge intensive commodities, is likely to be a natural capital saving. While NCE keeps equity and efficiency issues separate, SD strives to integrate them in a hierarchy; in practice, there is likely to be pragmatic convergence.

---

1 This paper was produced for Industry Canada under contract n^{0} U505-9-014. Research assistance by
Mr Mohamed Vafa, Phd student in Economics at the Universtity of Ottawa is gladly acknowledged

Author - Industry Canada
Publication Date - 2000-03-31

Table of Contents

Author - Industry Canada Publication Date - 2000-03-29

Productivity and Sustainable Development: Micro Fundamentals.

Philippe Crabbé,[2]
Institute for Research on Environment and Economy,
University of Ottawa

> "Although we cannot predict the future, we know that it will have to conform to the laws of nature and of dynamic systems, to the restrictions of a small planet, to the constraints of ecological systems and the availability of resources, and to the peculiarities of human individuals and human society. This constrains future development to certain riverbed - not everything is possible, and many paths that seem possible at first sight turn out to be inconsistent and impossible if their whole-system implications are considered." (H. Bossel, Earth at a Crossroads, Cambridge University Press 1998)"

1. Introduction

Sustainable Development (SD) and Neo-Classical Economics (NCE) provide different but overlapping perspectives on how society may address economic, environmental and social challenges as well as productivity concerns. While NCE is at a relatively mature state of development, SD is still at the early and formative stages..

The aim of this paper is to investigate the relationship between productivity and SD and NCE. A key purpose is to help clarify where both NCE and SD could support societal efforts to improve productivity (i.e. where do the two perspectives concur). In order to achieve this, the paper seeks to identify the areas of divergence as well as convergence between the two perspectives. The paper offers a horizontal coverage of the issues by casting a wide net albeit at the expense of vertical depth.

SD is first and foremost about ethics, about what we should sustain. As efficiency is the supreme value in the utilitarian ethics which underlies NCE, equity is the dominant value in the ethics of sustainability. Equity applies to generations through time and to countries, regions and other communities and groups within a generation through space. What we should sustain is not simply one component of an interdependent system, say the economy, but the whole system itself, the biosphere. The biosphere includes humans and other biotic

and abiotic components. Equity fundamentally means keeping open or improving opportunities for all components; this is the contractarian view of distributive justice (Howarth, 1998). Equity requires respect (e.g. human rights) and, in the human sphere only, empowerment (bottom-up) and subsidiarity (top-down).

Empirical evidence shows some decoupling between real income per capita and well-being (Osberg and Sharpe, 1999; Scott, 1995). According to Neo-classical Economics, productivity, especially labour productivity, is key to real income per capita. SD emphasizes development, quality of life. It places more emphasis on capital stocks as amenities and sources of wealth than Neo-classical economics, which tends to focus on flows such as GDP per capita. However, it is important to remember that as long as gross investment is positive and covers maintenance, income per capita will increase if population is stationary (Scott, 1995).

While being equitable, a SD path must also be flexible, evolutionary and self-organizing as to allow diversity of adaptive and innovative responses to new challenges currently uncertain. In other words, an SD path must also be productive. An SD path is not unique. It is an attractor in a non-linear dynamic system, much like a riverbed which allows a river to take different courses (Bossel, 1998; Report of Commissioner, 1998). Many sustainable scenarios have been developed in the last thirty years and they all fundamentally agree on sustainability principles and processes (Bossel, 1998).

Many if not most sustainable scenarios agree that the industrial economy needs fundamental re-thinking; it needs a "Next Industrial Revolution"(Hawken, 1995; Commissioner, 1998). Under many of the scenarios, the position is taken that a sustainable society will have to allow for development without physical growth in matter, energy and population (Ayres, 1998). International institutions and national governments still confuse sustainable development with unlimited growth. Sustainable Development is about limits. Our economy is embedded in a physical environment which is finite. Substitutability possibilities for environmental services are limited. Technological solutions to environmental degradation are limited if only by the second law of thermodynamics. Some aggregate measures of material and energy use may have to be drastically reduced if we want to reach a sustainable economy, say by the middle of the 21st century. Our current relative wealth has been achieved through the exploitation of our natural capital i.e. our natural resources, the waste absorption capacity of the environment and the biogeochemical cycles. Some component of our natural capital can be substituted for but some substitution may not be feasible for others such as for the biosphere itself and its ecological functions. It seems, for example, that the availability of arable land and its productivity per capita are declining and the trends are unlikely to be reversed in 20 or 30 years (Ayres, 1998).

According to a recent poll, four fifths of Canadians believe that increasing productivity is essential to improving their standard of living and should be a high priority for Canadian governments over the next five years behind health care but ahead of tax cuts[3]. However, Canadian empirical evidence on environmental degradation and remedial policies seems to suggest that ,at least, for one factor of production, natural capital, productivity is too low.

Indeed, in Canada, the industries that perform least well in controlling emissions are the ones which have the most toxic emissions (as measured by a toxicity index). They are refined petroleum and coal, chemicals, rubber and plastics, paper and allied products, and

non-metallic minerals. Overall, emissions per job and per dollar of output from Canadian manufacturing industries are 50% higher than releases from corresponding US manufacturing industries. The carbon intensity in Canada - carbon dioxide is one of the main Greenhouse Gases - is 30% above OECD average and Canada is the third most carbon intensive economy in the OECD. There is practically no federal tax with an environmental purpose in Canada (Technical Committee, 1998).

Like globalization, sustainable development is global in character. Given the current world population (5.3 billions in 1995) and the expected world population in the middle of the next century (8-10 billions), it may not be possible at the same time to protect our environment, increase economic development in the developing world and maintain our current material-energy consumption technology trends (Ayres, 1998). It is clear that the changes will require both investments and technological change. In particular, we will have to begin to phase out fossil fuels if we want to mitigate climate change. The substitutes to fossils fuels are large hydro projects, photovoltaics, biomass cultivation, nuclear energy, and energy conservation and increased efficiency (Ayres, 1998).

The US President's Committee of Advisors on Science and Technology has, besides climate change, identified four other areas for a science and technology agenda. These are: biodiversity (sound management), energy (efficiency and renewables), ecosystems (sound management), food supplies (cultivation, biotechnology, integrated pest management, and water conservation) (US, 1997). It is significant that the OECD considers that a framework for a report on sustainable development could serve as the basis of a submission of the OECD to COP5 (United-Nations Framework Convention on Climate Change, Fifth Conference of the Parties)(OECD 1998). Depending on the composition of output, growth does not necessarily contribute to degradation of the environment. Income per capita increased by growth matters considerably if environmental quality is a superior good over some range of income, along the so-called Kuznets curve (Golding et al., 1995a; Arrow et al., 1995).

One potential logic for action is first to identify the most severe threats and the technically feasible alternatives to current trends. Second, it is to try to identify the areas of agreement and the ones of severe disagreement within society about what constitutes sustainability. Third, it is to show how to get from here to there through backcasting for example. Are there technologies which allow for the increase of all factor productivities at the same time (win-win solutions) (Ayres, 1998)?

The paper is organized in 11 sections. After an introductory section, section 2 is devoted to a characterization of SD directly relevant for Economics: Development vs. Growth, the economic system as sub-system of the environmental system, weak and strong sustainability, the precautionary principle, no-regrets decisions and benefit/cost analysis, ecological and economic horizon, eco-efficiency and finally stakeholders' participation. Section 3 deals with the Neo-classical view on productivity gains and the latter's relation to growth. Section 4 deals with natural capital, the factor that SD focuses on. It considers voluntary economic instruments, the Porter Hypothesis and Eco-taxation as means towards increasing the scarcity of natural capital and stimulating innovation. Section 5 covers market environmental products and services such as eco-labelling and processes such as ISO 14,000. Section 6 tackles physical capital. The Neo-classical, the evolutionary and the ecological engineering perspectives on innovation are considered in turn. Section 7 deals

with human capital and information technologies which provide human capital with connectedness. Section 8 treats social capital and the rules of the productivity game. Section 9 deals with no-regrets solutions which increase both economic efficiency and sustainability. Section 10 concludes the paper by reviewing the areas of complementarity and differences between Sustainable Development and Neo-classical Economics.

---

2. Comments from Industry Canada staff and participants at a Resources for the Future seminar are gladly acknowledged, especially those of Mike Toman and Roger Sedjo. Remaining errors are mine

3. The Globe and Mail, March 16,1999(p.A6), referring to a poll conducted by Ekos Research Group and a chapter written by Ekos president F. Graves in the latest edition of *How Ottawa Spends*, published by Carleton University School of Public Administration.

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page

Author - Industry Canada

Publication Date - 2000-03-29

2. The Main Characteristics of Sustainable Development

It is customary to decry the ambiguities which are present in SD (Beckerman, 1994). This is not surprising since SD is essentially a political ideology and at a relatively early stage of conceptual development. However, there begins to be the rudiments of an economic theory of SD (Crabbé, 1997). There is still substantial disagreement within the SD constituency about whether growth can be sustainable or not and about whether sustainability is or ought to be weak or strong. Otherwise, there is a strong degree of agreement about the preeminence of equity in SD. Since the areas of conjunction and disjunction between Neo-classical Economics and SD are the object of this paper, the emphasis in selecting the following characteristic features of SD is on their relationship to efficiency. These features are: development vs. growth, the economy as sub-system of the environment, weak vs. strong sustainability, the precautionary principle and no regrets decisions, ecological vs. economic horizon, eco-efficiency and stakeholder' participation in decision-making. SD aims at a system in which equity is integrated with efficiency in a two-tiered hierarchical structure in which equity considerations form the first tier.

2.1 Development vs. Growth

Growth is quantitative.It is focussed on per capita GDP increases. Development is qualitative. It is a process as much as an end result (Pearce et al., 1992). It deals with the quality of life. National accounts allow us to measure growth. The growth rate is a scalar quantity. Indicators allow you to rank states of well-being according to a vector of indicators (multi-criteria objective) which can only be aggregated through a weighted sum in which the weights reflect the observer's values (Osberg and Sharpe, 1999). Development depends upon per capita consumption, net stocks of capital as a proxy for bequest to future generations, poverty and inequality, indicators of insecurity, etc. (Osberg and Sharpe 1999).

This already indicates that development cannot be separated from equity either intergenerational or intragenerational. Moreover, aggregated indicators of development are consistently decoupled from per capita GDP growth, at least in developed countries. While both indicate an upward trend, GDP growth shows a much stronger trend than a wide range of aggregated development indicators (Osberg and Sharpe, 1999; Daly, 1998). In other words, one may wonder whether policies targeted at increasing GDP actually are not missing the real welfare target (Daly, 1998).

It is customary to measure sustainability along three dimensions: economic, environmental and social. The environmental dimension is most concerned about natural capital (harvesting at sustainable yield) while the social one is most concerned about social capital. Economic sustainability is more concerned about both human and physical capital, the traditional domain of Neo-classical Economics, and about the complementarity among the four types of capital. However, all the three dimensions apply to the four forms of capital. At the firm level, there is a fourth dimension which matters; it is the financial one since traditional accounting deals exclusively with the financial aspects of the firm's performance (Commissioner, 1998).

Productivity growth may increase income but income growth need not necessarily increase well-being.

2.2 The Economic System as Sub-System of the Environmental System

Some people confuse sustainable development with sustainable growth. Sustainable physical growth is an oxymoron if the economy is only a sub-system of a non-growing ecosystem. We have but one earth! The environment is not growing. Physical growth is here interpreted as increased throughput of energy and material. Matter available as a finite stock only can be recycled (first law of thermodynamics) but energy, available as a flow of solar energy and as a stock of non-renewable energy, cannot be recycled (second law of thermodynamics). The ability of energy to do work decreases after each use. Since matter and energy are usually complementary in use, 100% recycling for matter is practically impossible as well. Therefore, even in a stationary state, there will have to be some physical throughput (Georgescu-Roegen, 1979). Economic growth will remain feasible only as long as we are able to increase value while minimizing material and energy throughput (dematerialization). Economic growth which increases material and energy throughput will always be at the expense of natural capital since some components of the throughput will be non-renewable and non-substitutable.

Natural capital is the limiting factor for sustainable development while knowledge is the limiting factor for Neo-classical Economics. For example, it is fish availability which limits harvesting and not the size of the fleet; it is the standing forest and not the sawmills which limits cutting; it is not pumping or refining capacity which limits crude oil available on the market but the crude oil available in the ground (Daly, 1998).

Efficiency is theoretically neither necessary nor sufficient for sustainability (Common et al., 1992). However, to the extent that increasing the scarcity of natural capital improves the overall efficiency of the economy as well as sustainability, it seems that increasing the productivity of natural capital will necessarily improve both. Therefore, environmental economics will be useful for sustainability (Crabbé, 1997; Toman et al., 1995).

2.3 Weak and Strong Sustainability

Weak sustainability corresponds to the smooth convex isoquants one finds in the Neo-classical theory of production; it admits a few exceptions. Strong sustainability is akin to Leontieff technologies. The factors of production are: natural capital, physical capital,

human capital and social capital. Natural capital corresponds to natural resources, the absorption capacity of the environment for wastes and the life-supporting biogeochemical cycles. Social capital is more or less narrowly defined and corresponds to the organisational capacity of a society. According to some definitions, it includes the society's cultural capital as well. Strong sustainability emphasizes the complementarity between other factors of production and natural capital. Critical capital is the portion of natural capital - whether it is weakly or strongly sustainable - which is essential in the Neo-Classical sense that no production can occur without it and such that its marginal productivity goes to infinity as it goes to zero as an input in production (Dasgupta et al., 1979).

Weak sustainability extends the Neo-classical theory of economic growth to natural capital. It essentially maintains the result that technological change and capital accumulation compensates for the exhaustion of non-renewable resources. This result is achieved through the assumed existence of a backstop technology, or of a sufficiently high elasticity of substitution among the factors of production, or still of an increase in their average productivity over time. There are obviously physical limits to weak sustainability dictated by the laws of thermodynamics; one cannot grow the earth's supply of grain on one acre of land (Page, 1998; Toman et al., 1998). Weak sustainability implies that the aggregate value of capital should be kept non-decreasing across generations. Weak and strong sustainability differ by the degree of complementarity assigned to factors of production. Strong sustainability is more pessimistic about the ability of technological progress to compensate for exhaustion and to prevent a slowdown in economic growth (Faucheux 1998a).

Renewable resources have substitutes. For example, there is aquiculture for wild fish harvesting, there is silviculture for tree harvesting in the wild. However, all these substitutes are more intensive in other factors of production such as human capital and often substitutes are not of comparable quality (Daly, 1998).

According to recent Neo-classical literature, there is a 3-way complementarity between physical and human capital and with technological progress rather than substitution (Boskin and Lau, 1992). Thus increasing productivity requires working on the three factors of production simultaneously since it is impossible to increase the marginal productivity of a factor without increasing the availability of the others (see graph 1; Daly, 1996). Therefore, an increase in the marginal productivity of a factor under strong sustainability, necessarily increases total productivity. If natural capital is also a complementary factor of production, a coordinated four-pronged policy aimed at each form of capital will be required.

Daly provides three arguments in favour of strong sustainability. If natural and physical capital are perfect substitutes, why accumulate physical capital since natural capital is already there? Second, physical capital is made from natural capital. More physical capital, therefore, requires more natural capital. This is precisely the definition of complementarity. Third, more fish harvested requires more fishers and more boats; again, this is the complementarity argument (Daly, 1996).

Strong sustainability has been discussed above on positive grounds.[4] It could also be discussed on ethical grounds. Strong sustainability has been compared to occupying a friend's house and restoring it when one moves out to the way one found it when one moved in (Howarth, 1998; Page, 1983). Strong sustainability results from property rights assigned to future generations. Violations of these property rights would be subject to

compensation (and therefore substitution) if there were a way to evaluate the loss to future generations. If there is no way to evaluate this loss, property rights become inalienable and no longer the subject to compensation; strong sustainability only is feasible (Howarth, 1998; Bromley, 1989). Strong sustainability implies that the value of natural capital should be kept non-decreasing over generations.

2.4 The Precautionary Principle, No-Regret Decisions, and Benefit-Cost Analysis

The precautionary principle or safe minimum standard is an ethical principle whose foundations - not found in Neo-Classical Economics - are rather muddled (Farmer et al., 1998; Howarth, 1998).[5]

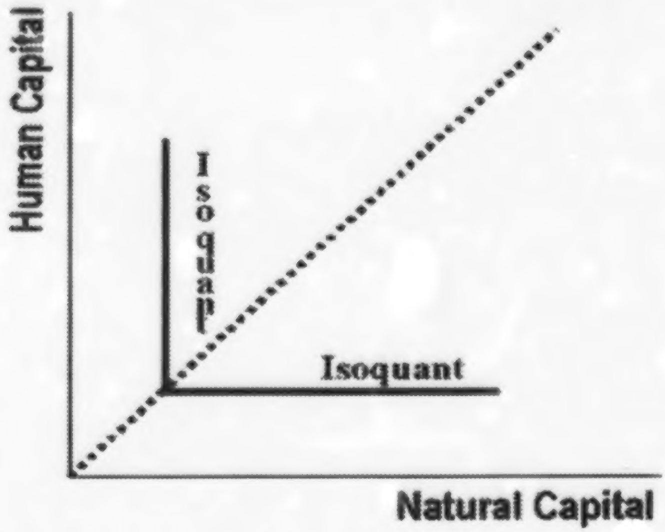


Figure 1: Complementarity Among Factors of Production: Natural Capital and Human Capital. The Figure Could Be Extended to Four Dimensions, Encompassing Physical Capital as well as Social Capital.

It says that under conditions of uncertainty - not of risk - when there are consequences which are irreversible, one ought to be risk-averse in taking decisions.[6] The degree of risk-aversion is not determined and could go all the way to infinity. In the latter case, no irreversible decision will ever be undertaken. There is a limit to the applicability of the principle i.e. the opportunity cost of the decision cannot be "too large". In the context of benefit-cost analysis, it would mean that the net benefit of an irreversible decision ought to be "quite large" before being undertaken. The precautionary principle is adopted by the 1995 French Environmental Protection Enhancement Act (so-called Barnier Act) and is formulated as follows:

"Absence of certainty, given the current state of scientific and technological knowledge, must not delay the adoption of effective and proportioned measures aiming at preventing a risk of substantial and irreversible damage to the environment at an economically acceptable

cost" (Mondello, 1998, p.12 referring to February 2, 1995 French Environmental Protection Enhancement Act # 95-101).

Actually, the precautionary principle bears the weight of its philosophical and historical origins. It is rooted in contractualism i.e. the idea that moral obligations are based upon a binding agreement among beings capable of being moved by reason.[7] Its historical origins can be traced back to the German social-democrat environmental legislation of the 1930's which refers, as a first order principle, to the requirement of prudent negotiations among individuals (Vorsorgeprinzip) when there is uncertainty. One of its second order principles is the "polluter pays" principle i.e. responsibility (Verursacherprinzip) which must be balanced by another second order principle of economic feasibility (Wirtschaftliche Vertretbarkeit); the latter may require state intervention (Gemeinlast Prinzip) to protect significant economic interests (Mondello, 1998). This is probably where Von Ciriacy-Wantrup, the first economist to put forward the principle in 1952, found it! (Ciriacy-Wantrup, 1952).

The US CERCLA legislation which consecrates the strict or objective liability principle i.e. liability without fault or negligence, is an application of the precautionary principle. The obligation to substitute other products for toxic ones (e.g. CFC's) as feedstock is another application. Yet, another one is the regulatory obligation to undertake either control (prevention) or remediation (cure) antipollution investments (Mondello, 1998).

No-regrets decisions are decisions whose opportunity cost is nil. These decision opportunities exist when the economy is not Pareto-optimum, the usual case. Then, it is possible to take a Pareto improvement which yields benefits along several dimensions. An example would be, a decision which improves the economic efficiency of an activity at the same time as environmental quality. This is called a double dividend: one gets an economic gain in efficiency and an environmental gain at the same time. An example of double benefit or dividend is provided by green taxation. By shifting the tax burden from labour to natural capital, one allegedly increases the productivity of natural capital and, at the same time, increases employment if there are no rigidities on the labour market. Another example is that by increasing the scarcity of natural capital through economic instruments, one provides dynamic incentives to innovate ("Porter Hypothesis").

Benefit-cost analysis presupposes efficiency to the extent that it substitutes perfect market equivalent evaluations such as shadow prices in situations in which there are externalities. The precautionary principle is not related at all to an efficiency ethic while no-regrets decisions refer explicitly to situations in which efficiency has not been achieved and which can be improved upon.

2.5 Ecological and Economic Horizons

A major contribution of sustainability to economic decision-making is the requirement that decisions with environmental impacts adopt an ecological horizon rather than an economic one. Most economic horizons extend to fifty or sixty years, which is the economic horizon for the amortization of large physical infrastructures such as dams. Ecological impacts may extend for much longer periods e.g. climate change. By requiring longer horizons, the issue of intergenerational equity creeps in because there is complete power asymmetry between the current generation (dictatorship) and the future one (Page, 1998). Longer-horizons entangle economic issues in both efficiency and intergenerational equity problems. The

requirement of longer horizons than the one dictated by the discount rate does not invalidate the discount rate in sustainability decisions. It subordinates it to a lexicographic ordering in which intergenerational equity dominates efficiency. The discount rate belongs to the realm of efficiency while intergenerational equity requires, for example, that the value of the stock of capital be maintained non-decreasing from one generation to the next. Therefore, it becomes important to know whether this non-decreasing value is able to be maintained irrespective of the composition of aggregate capital or whether a necessary condition for this non-decreasing value is that the value of the stock of natural capital be itself non-decreasing, an issue related to weak vs. strong sustainability.

A similar argument holds in space. Equity requires that sustainability of a community may not be reaped at the expense of another one however far away. A measure of sustainability in space is supplied by the so-called "ecological footprint" (Wackernagel et al., 1996).

2.6 Eco-efficiency

The productivity of natural capital is too low because of externalities, public goods and property rights and policy failures. It is, therefore, necessary to increase natural capital productivity by transforming the economy from the production of goods into a production of services which will minimize throughput of matter and energy. This transformation requires changes in integrated technology systems which command long lead-time and are risky; some advocate that it requires a new industrial revolution (Hawken, 1995). Technological change must be both supply and demand driven and be supported by socio-economic changes. Closed-loop (zero emission) technologies, reduce, reuse, recycle (the three R's), cascade (modular structure of products allowing components replacement), repair services, life-time warranties are all components of an integrated technological system.

The fundamental challenge of sustainability is to increase the productivity of natural capital while, at the same time, increasing total factor productivity. This must be done by increasing the rate of natural-capital saving innovation and create new non-natural capital intensive services.[8] The market alone cannot do this because the problem is fundamentally an externality problem and there is no indication whatsoever that it is even beginning to address the sustainability problem (Ayres, 1998). However, the problem is not as simple as it appears. Anecdotal evidence seems to indicate that firms do not suffer from endogenous organizational weaknesses which prevent them from appreciating the financial benefits from a more integrated approach but rather hit exogenous barriers (see infra, p. 32). In the US, physical capital and labour costs are roughly 20 times energy costs (Goldemberg, 1996). Eco-taxation is one instrument one can use to increase the productivity of capital. To the extent that taxation is shifted away from labour to natural capital, one increases at the same time the productivity of labour and, possibly, employment (Daly, 1998).

Eco-efficiency hinges on a proper definition of income, Hicksian or sustainable income i.e. the one which leaves the productive capacity which generates it intact over a period of time. However, this definition of income is not respected by the System of National Accounts (SNA), by project evaluation and by international balance of payment accounting which all count natural capital consumption as income. Natural capital should be depreciated by consumption in SNA; user costs - the intertemporal opportunity cost of producing today an exhaustible resource rather than later - should be counted as costs in project evaluation; and

many exports such as petroleum or timber harvested beyond sustainable yield should be treated as sales of capital assets (Daly, 1998).

Natural capital needs investment. Renewable resources not managed on a sustained yield basis are invested in simply by waiting, by halting harvesting until the resource stock is replenished. The absorptive capacity of the environment as well as the biogeochemical cycles can be treated as a renewable resource. For example, climate may be considered as a renewable resource. Only non-renewable resources must necessarily be depleted as they are exploited. However, there is an optimal way of doing this which factors in potential substitutes. This is the essence of environmental sustainability.

There is some degree of complementarity between information technologies, biotechnology and eco-efficiency when the former assists in decreasing wastage of material through high-precision cutting for example (IC SD Strategy, 1997; OECD, 1999).

There is some empirical evidence for a positive correlation between eco-efficiency and economic performance as measured by rates of return for the largest companies worldwide (IC SD Strategy, 1997).

There is a need to develop eco-efficiency indicators against which firms may measure their eco-efficiency performance.

2.7 Stakeholders' Participation in Decision-Making.

SD is a "projet de société". All stakeholders in SD must be allowed to participate in collective decisions. SD cannot only be a top down approach. For example, consumers' involvement with business and government reduces the need for regulatory approaches (IC SD Strategy, 1997). This is not only due to gains in efficiency resulting from decentralized decisions. It also results from the large and unresolved uncertainties which affect natural capital and on which stakeholders have to agree by lack of scientific certainty. On the other hand, SD cannot be obtained through a bottom up approach only. Governments must be leaders, manipulate sticks and carrots to make sure that SD happens. The principle of subsidiarity applies to the extent that the leading organization/government must be the one which is the most appropriate for the matter under consideration. For example, climate change is more a matter of international and national governance while location and administration of landfill sites is more of a local character.

---

4. Another but a minority definition in terms of environmental damages of weak versus strong sustainability exists
in the literature on benefit-cost analysis (Barbier et al., 1990).

5. There is a slight distinction between the two principles (Howarth, 1998). The precautional principle amounts to the commitment of resources now to safeguard against the potentially catastrophic future effects of current activity. Since waiting through conservation is tantamount to investing, delaying a development decision is tantamount to a commitment of resources.

6. Strictly speaking, risk-aversion cannot be defined under uncertainty since a probability

cannot be defined as required by the Von Neuman axioms.

7. March; M. Kingswell, Book review of T.M. Scanlon's "Moral Theory, Moral Practice" in The Globe and Mail, 20, p. D11.

8. If factor complementarity stands, increasing the productivity of one factor automatically increases total productivity.

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page

Canada
http://strategis.ic.gc.ca

Author - Industry Canada

Publication Date - 2000-03-29

3. The Neo-Classical View of Productivity Gains and Their Relations to Growth

According to Neo-classical Economics, productivity performance and, hence, technical progress are the key to improving a country's living standards. Productivity is the relationship between output of goods and services and the capital inputs with the relationship usually expressed in ratio form. Both outputs and inputs are measured in physical units. Partial productivity is measured with respect to one factor of production - usually labour - while total productivity is measured with respect to an index of all the inputs. Productivity is affected by the quality and availability of factors of production but also by industrial structure and intersectoral shifts as well as by both microeconomic and macroeconomic factors (CSLS, 1998). Labour productivity overstates total productivity growth when physical capital and intermediate goods tend to grow faster than labour. However, both measures generally move in the same direction (Parry, 1997a).

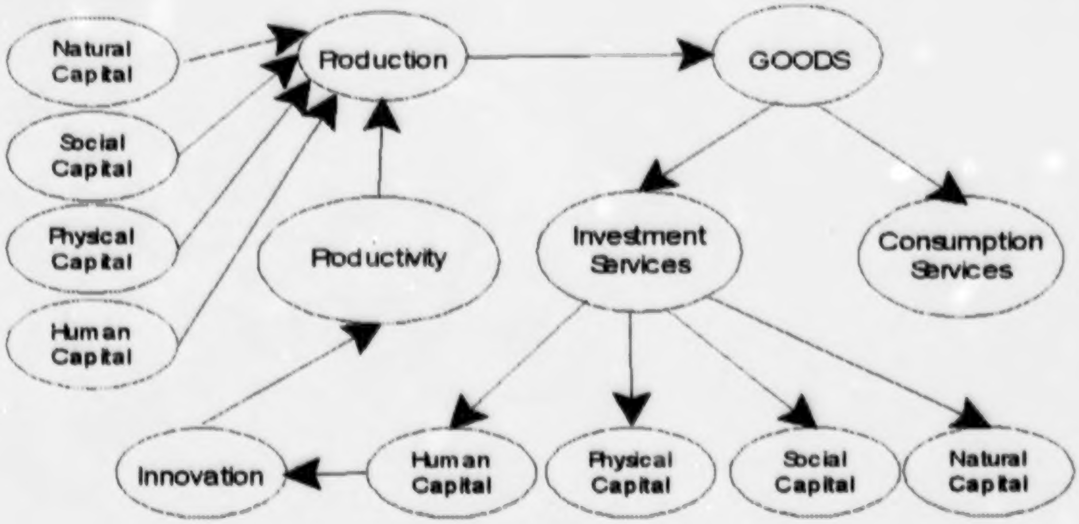
Productivity growth is the main engine of long-term growth. Neo-Classical Growth Theory's approach to productivity is heavily dependent on how it views the aggregate production function. The latter is constant returns to scale in the long-run - there is no fixed factor by the very definition of long-run - and isoquants are smooth assuming perfect susbstitutability of factors of production. In order for growth per capita to happen and be maintained in the Neo-Classical Growth Theory, exogenous (Hicks-neutral) technological progress must exist since the marginal productivity of the factors of production - human and physical capital - is assumed to diminish. The saving rate, being assumed constant, can contribute to the output level but not to its growth. Clearly, increasing the productivity of natural capital as required by SD is compatible with Neo-classical Economics since it would simply remedy overuse resulting from externalities. It would also lead to substitution of other factors of production for natural capital, including human capital.

The perfectly competitive assumption of Neo-classical Growth Theory does not allow for endogenous technological change since the latter has public good and increasing returns to scale features. Moreover, there is an empirically observed lack of convergence among the growth rates of various countries - and various regions of a same country - endowed with the same level of technological progress.

To wit, the Neo-classical Growth Theory allows, through costless labour-augmenting

technical progress, for permanent increases of output without increasing inputs and for output growth in a stationary economy with constant output per worker independently of investment/output.

The Endogenous Growth Theory literature, also rooted in Neo-classical Economics, has tried to explain endogenous growth and the lack of convergence phenomenon. It does not require the marginal productivity of factors of production to decline. This is because knowledge spillovers can occur among firms and sectors and human capital can provide external economies such as learning by doing. Learning by doing, being assumed to be subject to decreasing returns as well, requires the production of new products (horizontal innovation) or improvements in the quality of old products (vertical innovation) to allow growth to continue. An alternative approach is to allow imperfect competition in R & D with explicit treatment of patents and treat knowledge as a factor of production. Investment in human capital matters for technical progress which is now endogenous and there is a sharp distinction in the Schumpeterian Model of Endogenous Growth between investment in human resources and investment in material resources. Clearly, there is complementarity between innovation and human capital (see graph 2). In the context of SD, it will matter a great deal that the technology for producing knowledge i.e. innovations, is "greener" than the one producing physical capital (Aghion et al., 1998).



Graph 2: Total Productivity, Endogenous Growth and Innovation

The basic economic justification for science and technology policies in the post-war period has been the market failure argument. Markets may fail to operate efficiently for a variety of reasons (uncertainties, asymmetric information, economies of scale, externalities in knowledge-production, etc.). If left alone, market forces typically generate too little R & D (OECD, 1997b).1998). Given that the productivity gap in Canada results at least in part

from a comparison with the US, it is worth mentioning that over the period 1971-1997, physical capital per capita increased by 52.7% in the US while it increased by 77.8% in Canada. It seems that 80% of technological progress in Canada is embodied in physical capital (CSLS,The real stock of R & D increased by 58.5% in the US and by 135.5% in Canada. The 1997 level ratio Canada/US was 20.7%. Human capital increased by 47% in the US and by 40.5% in Canada. The level ratio Canada/US was 120.7% for 1997. The stock of natural resources fell by 39.6% in Canada while it fell by 39.5% in the US. The overall stock of capital rose in the US by 41.7% while it increased by 34.3 % in Canada. In 1997, the overall capital level ratio Canada/US was 72.7% (Osberg and Sharpe, 1999). In 1997, among the 300 top international companies, Canadian companies spent twice and a half as much on R &D as the US (The Economist, 1999). While these figures clearly satisfy weak sustainability (the overall value of capital does not decline), they do not satisfy strong sustainability since the value of natural capital has drastically declined over the period. Overall, in OECD countries, despite the introduction of higher quality products and processes and increased specialisation, observed rates of growth in income and productivity have generally fallen with respect to the earlier post-war period.

The new growth theories suggest that the chances of achieving sustainable growth depend critically on maintaining a steady flow of technological innovations. "If it had not been for resource-saving innovations, it is unlikely that our finite planet could have supported the expansion in material welfare that has taken place since the industrial revolution. Furthermore, although serious environmental concerns remain, especially concerning the global rise in emissions of green house gases and the depletion of ozone layer, the introduction of more environmentally friendly technologies has helped reverse the decline in air and water quality in many countries" (Aghion et al., 1998, p.151). Endogenous growth theory implies that "with enough innovations, particularly with the right direction of innovations, SD is within the realm of possibility" (ibid.).

For endogenous growth to be sustainable in the presence of pollution, it is necessary for the elasticity of intertemporal substitution for consumption to be less than 1 (or the elasticity of the marginal utility of consumption to be larger than 1). Pollution seems to be a more serious problem than the exhaustion of non-renewable resources to the extent that the aforementioned constraint does not apply in the latter case. In the case of pollution, increased output decreases the optimal pollution intensity which in turn decreases the marginal productivity of natural capital because of clean-up costs. However, if human capital accumulates at a faster rate than tangible (natural and physical) capital, the marginal productivity of natural capital does not decrease through increased output and the marginal productivity of tangible capital may actually increase because it compensates for the additional pollution cost of having more tangible capital (Aghion et al., 1998).

Technological progress has been labour-saving since the beginning of the industrial revolution and must have been multiplied by about twenty. This made sense when natural resources were abundant, the absorption capacity of the environment for waste was unlimited and population was relatively small. Today, labour productivity is high, population is large and natural capital is becoming scarcer. Efforts should now be devoted to the increase of natural capital productivity (OECD, 1997d).

The Hicks' "induced innovation hypothesis" is that, if natural capital becomes more expensive, the change in factor of production relative prices will induce inventions "directed

to economizing the use of a factor which has become relatively expensive" (Hicks cited in Newell, 1997. p.13). Empirical evidence in the energy appliances area seems to be in favour of the induced innovation hypothesis for the direction of the technical change, and more weakly for government induced minimum efficiency standards, together with a sizeable portion of autonomous technical progress explaining the rate of innovation. By extension of results found in the appliance area, one may surmise that eco-taxes could increase the eco-efficiency of the product menu (Newell, 1997).

Author - Industry Canada

Publication Date - 2000-03-31

4. Natural Capital: How Do Environmental Constraints Affect Productivity Growth?

Actions aimed at improving productivity of natural capital should aim to reduce resource use, reduce waste (the cost of waste disposal provides an incentive for this), and produce more durable products. Increased resource productivity requires closing materials and liability loops. Closing materials loops solutions consist in reducing the volume and the speed of the natural resource flow, in more intensive utilization of goods and in increasing their multi-functionality, and in allowing for substitution of components of the goods. Closing liability loops entail long-term warranties, minimum service life, and the use of used components in products which should be allowed through legislation (Meyer-Krahmer, 1998).

Preventing pollution at source can save money in materials and end-of-pipe remediation. Voluntary action in the present can minimise future risks and liabilities and make costly retrofits unnecessary. Companies staying ahead of regulations can have a competitive hedge over those struggling to keep up. New green products and processes can increase consumer appeal and open up new business opportunities. An environmentally progressive reputation can improve employee recruitment, employee morale, investor support, acceptance by the host community and management's self-respect (Ekins, 1998; Crabbé, 1997).

Three government policy instruments or incentives can be used among others to improve the productivity of natural capital: voluntary agreements, regulation and taxation.

4.1 Voluntary Environmental Instruments

"Historical evidence demonstrates an enduring gap between the most cost-effective technologies available for pollution reduction and the technologies actually in use. There is also a gap between what existing plant and equipment should be able to achieve in terms of efficiency and what in fact is achieved" (Goldemberg, 1996, p.134). Time lags occur as a result of the long turnover of the capital stock. New technologies are less reliable than the old ones and are not perfect substitutes for the old one in terms of the services they provide (Goldemberg, 1996).

Voluntary instruments take many forms. For example, an industry association may set guidelines and codes of practice for its members; compliance is a condition for association

membership (e.g. "Responsible Care" for the Chemical Producers Association). It may take the form of an agreement between a producer and an Environmental Non-Governmental Association (e. g. Merck-INBio biodiversity prospecting agreement). Yet another one is the Netherlands Environmental Covenants i.e. a dialogue between an industry and the government which leads to a formal agreement (CBC, 1996).

Voluntary agreements may provide industry with reputation, with support and incentives from the government; may pre-empt and be more cost-effective and flexible than command and control regulations; may provide industry with a more certain regulatory environment, more incentive to innovate and to integrate economy with environment, and may be more timely. Governments reduce administration costs of both complex environmental regulation and monitoring and increase cooperation. Voluntary agreements may provide opportunities for Environmental Non-Governmental Organisations to get involved (CBC, 1996)..

Some type of environmental regulation amounts to nothing more than increasing the cost of producing a negative externality. The regulation, therefore, provides the firm with an incentive to avoid the cost, for example, by shifting pollution from one medium to another (avoidance strategy). Another strategy for the firm is to be an environmental follower while using a course of action in which the environment is perceived as a problem of compliance (Faucheux, 1998).

Voluntary environmental instruments may amount to regulatory capture and confer a firm a competitive advantage whose environmental value may be questionable. Voluntary instruments give rise to free-riding, principal-agent relationships with their drawbacks of incomplete contract, moral hazard and adverse selection (Faucheux et al., 1998). Accountability and transparency to the general public may then be compromised. The effectivenenss of voluntary agreements may depend upon the policy mix (CBC, 1996).

Covenants between industry and governments are one type of voluntary agreements which rely on social capital. Covenants may allow the participation of stakeholders other than the parties to the agreement. For example, ENGO's need not sign the covenant but could be allowed to provide their point of view in negotiations leading to the covenant. Covenants focus on far-reaching environmental improvements and not on end of pipe or incremental measures. Covenants avoid surprises and allow smooth introduction of adaptations to standards. They involve CEO's in signing up, provide feedbacks, maintain a multimedia integrated approach, remain focussed on policies, provide industries with flexibility, maintain strong relations with internal environmental management in firms. The technological objectives must be longer term and be selected to catch the "big fish". Covenants appear to work better when there are only a few big players in the industry. When players are diffuse, enforcement (monitoring) of the covenant is difficult and regulation may be a better tool. Therefore, covenants would not appear to be substitutes for regulation (de Jongh, 1998).

The Canadian "Responsible Care" and its policy complement, the "Accelerated Reduction/Elimination of Toxics in Canada" (ARET) are probably the closest approximations to covenants we have in Canada. The latter program involves federal and provincial governments as well as industry associations, labour and environmental groups to define toxic substances and develop phase-out targets and schedules. This program provides industry with targets against which measure performance. Neither program is a covenant

since they amount to unilateral commitments rather than bilateral agreements with governments (CBC, 1996).

4.2 The Porter Hypothesis

One win-win strategy or no-regrets solution is the one identified by the so-called Porter hypothesis i.e. that environmental regulation is a dynamic source of innovation at the firm level and competitiveness at the national level (Porter et al.,1995). Rather than implementing an environmental regulation or being a follower in developing ecoproducts, the firm adopts proactive environmental strategies. Often innovations of this type favour concentration and the constitution of firm networks e.g.. for processing waste, packaging, etc. These innovations are costly and seldom accessible to small firms (Faucheux et al., 1998). However, the rationale and empirical evidence in favour of the Porter hypothesis or its converse i.e. that environmental regulation decreases competitiveness, is not strong (Palmer et al., 1995; Jaffe et al., 1995). Some proactive strategies seem advantageous in the short-run but may prove to be unsustainable in the long-run while firms are locked in environmentally suboptimal strategies (Faucheux et al., 1998). It has been shown in a vintage model of physical capital for the profit maximizing firm subject to an environmental policy that two effects are at work: a static productivity (downsizing) effect and a dynamic profit-emission (modernisation) effect. The first indicates an increase in the average productivity of physical capital if the firm's downsizing caused by the policy takes the form of eliminating less productive older and cheaper machines. The second indicates that both profits and emissions decrease at the margin with a stricter policy; however, this effect is smaller on profits and higher on emissions if the firm's downsizing affects heterogenous vintage capital than in the homogeneous vintage case. Therefore, if this model is a correct representation of the real world, downsizing and modernisation rather than innovation (profit increase) are at work. However, both competitiveness (average productivity of capital) and environmental quality (decreased emissions) may be enhanced. (Xepapadeas et al., 1999).

4.3 Eco-Taxation

Environmental taxes achieve environmental goals at lower cost than command and control (static efficiency) and provide continuous incentive for technical innovation (dynamic efficiency) (OECD, 1997a). The same conclusion could be applied to tradeable pollution permits (OECD, 1997a). Removing subsidies which are detrimental to the environment and sending truer price information to consumers could be a first step. For example, it is estimated that in the US, only 79% of the total cost of road infrastructure and services is paid through road-related taxes and tolls. Agricultural subsidies which contribute to increase the use of fertilizers are 2% of OECD GDP. In the US, only 25% of irrigation cost is recovered through user charges (OECD, 1997a). There are subsidies to fisheries, depletion allowances in excess of development and extraction costs for minerals, etc.. There are many subsidies to transportation (OECD, 1997a). In Canada, the taxation rate for fuels is negatively correlated with their pollution intensity (Technical Committee, 1998). Eco-taxes are applied to products that create pollution either when they are manufactured, consumed or disposed of (OECD, 1997a). There are limits to substitution possibilities for some commodities which are subject to taxes such as energy and transportation. This means that these taxes will provide sustained revenue, an important objective in taxation policy (OECD, 1997a).

When environmental taxes are applied to polluting products, they increase the relative price of these products creating a permanent incentive to use and manufacture less polluting ones.

Even with eco-taxation, it is necessary to keep income taxes for distributive purpose to compensate for the regressive character of green taxes (Daly, 1998). Green taxes are often applied in a revenue-neutral context i.e. a tax increase on natural capital is concomitant to a tax reduction on labour and physical capital. Eco-taxes are small but a growing share of revenues in OECD countries (OECD, 1997a).

Making natural capital scarcer through taxation will increase its marginal productivity and thus increase the efficiency of the economy. Shifting taxation from labour to natural capital will decrease labour marginal productivity and, in the absence of labour markets rigidities, increase employment. This is the essence of the so-called double dividend hypothesis, a win-win solution.

The evidence in favour of the double-dividend hypothesis is mixed in OECD countries (OECD, 1997a). This evidence is based on simulations which indicate there is a positive effect on employment but it is small and, therefore, it will not be able to provide a structural long-term solution to the unemployment problem. This is because one has to take labour market rigidities into account and because workers may end up paying a substantial portion of the environmental tax, thereby, not really reducing the "tax wedge" (tax burden) on labour. Reducing the tax wedge may require a substantial increase in the rate of environmental taxes. Finally, to the extent these are successful in reaching their goal i.e. in decreasing the use of natural capital, their tax base is reduced. Finally, environmental tax revenues should go to general revenues (and not be earmarked for the environment) for the tax to remain neutral.

There is little evidence about the distributional impact of environmental taxes. Many studies have been conducted on the carbon energy tax and concluded that this tax would be moderately regressive; this is true for Canada as well (Hamilton and Cameron, 1994; OECD, 1997a).

Environmental policies (including eco-taxes) and relatively high environmental standards have had a limited impact on competitiveness whether for individual sectors or for economies as a whole. Location decisions to so-called pollution havens are almost inexistent. Actually, to the extent that environmental policies increase efficiency, they may actually improve long-term competitiveness but perhaps not in the short-run (Kuznets curve argument). Common policies adopted by several countries reduce the risk of leakage (the pollution haven increasing its emissions as a consequence of a neighbour's environmental policy) which simulations indicate may occur. The impact of an environmental tax on competitiveness depends upon the way the revenues of the tax are used and may actually raise GDP (OECD, 1997a).

Environmental taxes are indirect taxes which fit nicely in the trend to shift away from income taxation. In some Scandinavian countries and the Netherlands, environmental taxes amount to 5-10% of tax revenues and 2.5 to 4.9 of GDP (Technical Committee, 1998). Sweden has Pigovian taxes on transportation and energy. Since 1991, it has been very successful in terms of emission reduction (Kuntze, 1998). In Canada, it has been suggested

to replace the federal fuel tax by a broader base environmental tax which could actually increase competitiveness with the US (Technical Committee, 1998).

It has been asserted that eco-taxes are more efficient at stimulating improved abatement technologies i.e. environmental technologies, than tradeable permits and the latter are more efficient than command and control. This is because, the argument goes, the innovating firm may not be able to appropriate the full social benefits of a new technology when there are spillovers to other firms. The gain in efficiency is negligible in the first case and somewhat larger in the second (tax vs. regulation) unless reduction in abatement costs is very large. The inefficiency due to spillovers is found to be negligible due to open access character of the market for innovations (Parry, 1998).

Author - Industry Canada Publication Date - 2000-03-31

5. Markets, Productivity and Sustainable Development

The demand-side approach to innovation emphasizes procurement, labelling, performance specification and concertation of user groups. According to two recent Japanese studies, 40% of the world production of goods and services over the first half of the 21st century may be from environment-energy linked products and technologies (Faucheux et al., 1998).

Technological advances fuel the emergence of new products and services such as electronic commerce and network-based services. Governments have a role in shaping these new markets. Development of new demand initially requires appropriate supply side conditions. Regulatory reform, the dissipation of public monopolies (e.g. telecommunications) and the removal of product barriers within and between sectors are essential in this respect. New products such as multimedia audio-visual goods and services require adjustments to regulation, competition, intellectual property rights and market access so that market structures for audio-visual content production and delivery are available to meet latent consumer demand. Concerns for pluralism in ownership and cultural creativity and diversity in content should be reconciled with policies based on non-discrimination and open competition. Furthermore, competition policy must balance the need to achieve economies of scale and scope through vertical integration with the need to ensure that smaller firms have access to networks and markets.

A range of new services are being developed in OECD countries such as multimedia and environmental services that are so widespread in their potential application in industry and the home that they may provide a basis for renewed macroeconomic growth and job creation. However, these services are often formed through new combinations of elements from existing highly regulated sectors, a situation which creates many barriers to new product development (OECD, 1997b).

Two instruments have been introduced by the market in the environmental area. They are eco-labelling and the International Standard Organization (ISO) 14,000 series of environmental standards. The first attests to the environmental quality of the product while the second attests to the environmental quality of the process through which it was produced. Both eco-labelling and ISO 14,000 share into the benefits and drawbcaks as other voluntary environmental instruments.

5.1 Eco-labelling[9]

Some scattered anecdotal evidence shows that sales have increased when an ecolabel has been obtained for a product, but there is no statistical data to show the market power an ecolabel may confer on a product. Producers continue to apply for and pay for ecolabels, indicating they have some market value. It is difficult to separate out the market impact of the ecolabel from other factors which influence a product's market share.

Eco-labelling programmes have been more successful in countries which benefit from a higher consumer awareness of environmentally preferable products. Environmental NGOs, media and consumer groups have contributed to this awareness. In some cases, such as detergents, they have had a strong impact in some countries.

Criteria are set up in such a way that only a small proportion of products in a product category can obtain the ecolabel. However successful ones tend to exceed 30% of the market in a product category because they become the standard. If the product is highly traded and contain production and process criteria, it may constitute a trade barrier to foreign competition whose products may not conform; this problem is especially acute for products originating in LDCs.

Ecolabels are considered an effective mean to communicate the environmental qualities and overall quality of a product. They are generally granted to products but the Canadian Environmental Choice program develops them for services. It is an education tool for the public who can obtain green products shopping guides. Environmental quality becomes a significant competitive factor only when overall competitive quality standards have been achieved.

Most ecolabels are developed for products which reduce environmental damage during the use and disposal phase. They encourage the use of recycled products to limit waste generation and limit consumption of nonrenewable resources. Few ecolabels refer to the production phase of the product. Some deal with the whole life-cycle of the product; this is the ultimate goal of eco-labelling.

Besides these so-called type I ecolabels, there are type II eco-labelling schemes which amount to a unilateral declaration by the producer and type III for which there is independent verification according to preset quantitative criteria.

Ecolabelling like other voluntary instruments increases the productivity of natural capital at least in pollution avoidance. It is extremely difficult to isolate the environmental impact of ecolabelled products from other environmental measures. There is some anecdotal evidence but no hard data to substantiate the claim that ecolabelling has increased the demand for products. As mentioned above, their degree of success depends very much on consumer awareness. Often, producers adopt ecolabelling by fear of losing market shares rather by the drive to increase market shares. Research has shown that ecolabelling is more a complementary competitive factor rather than a substitute for more traditional ones.

5.2 ISO 14,000

The ISO 14,000 series is a set of standards which may be required soon by banks extending credit to businesses. ISO 14,001 is the most important standard of the series because it is

the reference standard to be used by organizations wishing to have their environmental management systems officially certified/registered by third party registration body. The standard is based on the fundamental concepts of quality assurance and total quality management summarised in the ISO 9,000 series. An environmental policy implementing ISO 14,001 not only acknowledges best available technology but also emphasizes the importance of material susbstitution wherever possible, process improvement/optimization, and waste and pollution reduction and eventual elimination. The standard applies to any organization that wishes to:

a) implement, maintain and improve an environmental management system;

b) assure itself of its conformance with its stated environmental policy;

c) demonstrate such conformance to others:

d) seek certification/registration of its environmental management system by an external organization;

e) make a self-determination and declaration of conformance with an international standard (Lamprecht, 1997). Industry Canada has assisted in developing and implementing a program of accreditation for ISO 14,000 registrars and a certification program for environmental auditors (IC SD Strategy, 1997).

---

9. This section is entirely based upon OECD, 1997c.

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page

Author - Industry Canada Publication Date - 2000-03-31

6. Physical Capital: Innovation, Productivity and Sustainable Development

The sustainable character of a technology is recognized by its features of being eco-efficient rather than throughput-increasing (matter and energy) and by its substitution of renewable resources to non-renewable resources (Daly, 1991). A natural capital augmenting technological progress is one which is integrated while reducing waste over the life cycle of a product rather being add-on or an end of the pipe technology. Examples of the former would be: chlorine-free chemical processes, organic fuels, photovoltaic energy generation, etc..

The barriers to technology dynamics and penetration are: uncertainties about long-term prices, entrenched oligopolies and monopolies, established regulatory bodies, institutional separation between technological decision-making and decisions by consumers often endowed with very high discount rates, lack of technical information, lack of adequate intellectual property protection, regime of technological appropriation, path dependence of the evolution of knowledge, inability to reap network externalities, and perverse subsidies (Ayres, 1998; Archibugi et al., 1998: Goldemberg, 1996; IPCC, 1999). Oligopolies and monopolies occur whenever there are increasing returns to scale or tipping (a technology becomes dominant and excludes the others). The existence of these barriers is proof enough that the economy is not at a Pareto optimum and that no-regrets opportunities may be significant (Ayres, 1994).

Technology diffusion initiatives and services can be improved through the use of best practices at all levels (OECD, 1997b).

There are two perspectives on innovation to the extent the latter affects physical or, more generally, tangible capital (physical and natural). The first one, the Neo-classical one, emphasizes the sequence invention-innovation-diffusion as market processes tied to knowledge, in the Schumpeterian tradition; the second one, the so-called evolutionary one, tends to emphasize the network features of innovation systems with their ties to institutions other than the market i.e. social capital generally, and the integration of the environmental dimension in the system.

6.1 Neo-Classical Perspective

Technological change is the process by which economies change over time, in terms of the

products they produce and the processes used to produce them. This is the Neo-classical concept of productivity. In the Schumpeterian sense, an invention is "an idea, a sketch or a model for a new improved device, product, process, or system" while an innovation is its commercialization. Diffusion is the process through which the innovation spreads through the markets. Induced innovation is the one which results from one factor of production becoming more expensive. Input innovation results in reduced factor cost; joint input/output innovation reduces both factor costs and the output mix; output innovation results in a change in the output mix (Newell, 1997).

Technology diffusion or the widespread adoption of technology by users other than the original innovator is necessary for realising economy-wide benefits from innovation in terms of productivity gains and job creation. The efficiency gains from the adoption of new process technologies - including the commercialization of "orphan" ideas (clever ideas that fall by the wayside) - has been one of the major factors behind rising real wages, while the introduction of new products has been a major force in creating new jobs (The Economist, 1999). Policies to support diffusion should at the same time support the socialisation of the technology and raise the private returns of innovating firms through stimulation of supply and demand for new products and processes. It is a process involving the interaction of a variety of private and institutional actors and networks. Central to the process is both codified and tacit knowledge that are integral parts of the technology (OECD, 1997b). "To stand any chance of success, [innovations] have to be transferred as concepts embedded in people's heads" (The Economist, 1999, p. 21).

6.2 Evolutionary Perspective

The overall innovation performance of an economy depends not so much on how specific formal institutions perform, but on how they interact with each other as elements of a collective systems of knowledge creation and use, and on their interplay with social institutions. Innovation systems exist in various forms such as national or regional innovation systems, clusters of industries, or technological systems. Their functioning is not determined by market forces alone but also by the logic and operation of various institutions with different incentive structures.

The evolutionary perspective on technological change considers the latter as endogenous, related to economic incentives, technological opportunities, and embodied in the prevailing organizations and institutions. The economy's ability to create sustainable development depends on its ability to generate technological change, to adapt its organisational forms, the institutions and the patterns of demand to support this change. There is a current lock-in in polluting technologies because of positive externalities under the guise of dynamic scale and learning effects, particularly important in the diffusion phase. Because of the existing routines, present tasks and qualifications, and existing user-producer relationships, the diffusion of a new technology is rather difficult and proceeds slowly (Lahaye et al., 1996).

In the analysis of technological changes, three categories of players can be identified (Faucheux et al., 1998) :

1. Private and public research and development departments whose work determine the content of technical change.
2. Government regulatory institutions which influence the direction of technical change.

3. The firms who take market conditions into account to reconcile the opportunities offered by the former with the constraints imposed by the latter.

Technologies are created by firms. Research activities inside the firm are the dominant form of organisation for industrial innovation. The integration of R & D activities inside the firm facilitates the exchange of information from research to implementation. Firms produce innovations on the basis of their own technology supplemented by contributions of other firms and public knowledge. There are elements of accumulated technologies and skills specific to the firm that cannot entirely be transferred through market and information channels. A number of innovations and improvements are produced by firms from learning by doing and learning by using on the basis of state of the art technology in use. The innovation process is embodied in organisational routines in which knowledge from the past is encoded for innovation and which are either refined or transformed by the learning organisation. "Once the cumulative and firm-specific nature of technology is recognised, its development over time ceases to be random, but is constrained to zones closely related technologically and economically (e.g. related markets and distribution networks) to existing activities" (Dosi, 1988, p. quoted in Lahaye et al., 1996). For complex new technologies, there is learning which comes from use by the final user.

End of the pipe technologies are only the result of minor departures from existing routines and are linked to scientific and engineering principles on which they are based. Most companies still have no idea of the amounts of pollution and waste they are producing and thus are unable to undertake elementary assessments to minimise waste and save raw materials. Environmental issues appear at the end of the process. Chemical destruction methods, for example, are based on combustion and biological processes. A generally accepted framework exists for guiding R&D to improve the performance of waste destruction and separation technologies. The integration of environmental issues implies a modification of environmental routines. Such a modification must allow the internalisation of the environmental dimension in the decision rules and the assessment of the different alternatives. Firms and regulators progressively take the environment as a strategic opportunity. The innovative firm does not respond to pre-existing niches but seeks to influence consumer demand (Faucheux, 1998).

Networks involving complementary and competing firms, between users and producers of a technology, between research centres and industries and between industries and government agencies matter a great deal. This is especially important for clean technologies. Networks reduce the uncertainty attached to the development and the adoption of clean technologies and increase know-how and reduce irreversible commitments. Consumers may decide that a technology is superior to another one on the condition that everybody moves at the same time. This move could be made easier if current product or process is not embedded in specialised equipment. Here negotiations among the partners are crucial. Technological change requires more than technology alone; it must be systemic. The social and institutional context in which the technology is to be applied has to change as well. An example is the introduction of the electric car (Crabbé, 1997).

The creation of an environmental industry creates a new organisational set up but it tends to develop end of the pipe technologies. Early adopters of the new technology bear a disproportionate share of the transient incompatibility costs. Incentives from government are required to encourage the switch. Regulation should influence the direction of

technological change rather than being a constraint (Lahaye et al., 1996).

Technology-oriented business start-ups are a source of diversity, flexibility and long-term performance. They play a unique role in pioneering and developing new markets and providing diversity in fragmented existing markets characterized by risk/reward ratios which are dissuasive to large firms.

In the Neo-classical perspective, the emphasis will be on the input innovation mechanism if natural capital is made scarcer through a price increase as a way to achieve SD. In the Evolutionary perspective, SD will be achieved through alterations of environmental routines and the internalization of the environmental dimension in the innovation system.

6.3 Ecological Engineering Perspective

Ecological Engineering aims at closing the material cycle through cleaner processes, recycling of waste product and dematerialization (reduction of input/output). According to this perspective, consumption must not be defined by purchase of products alone but also by purchase of services.

Recycling reduces the quality of a material over time because of the second law of thermodynamics.[10] Many products were not designed with recycling in mind, thereby, rendering recycling very inefficient in terms of energy and material use (McDonough et al., 1998). Ecological engineering tries to mimic the functioning of ecosystems which are not efficient from the energy and matter point of view but which are regenerative.

Ecological Engineering emphasizes the cyclical cradle to cradle management rather the linear cradle to grave management; waste must be feedstock. "Products that do not biodegrade should be designed as technical nutrients that continually circulate within close-loop industrial cycles - the technical metabolism" (McDonough et al., 1998, part three, p.1).

Technical metabolism is not simply recycling; it allows materials to retain their quality. The ability of these products to generate services would never be impaired. Actually the company making it would own the product or, at least, the material and simply sell the service. The more services a product can generate, the more flexible it is to changes in tastes.

Next to the technical metabolism, there is the biological one in which things are biodegradable and return to the organic cycle. The two metabolisms should be kept separate. Packaging should be biodegradable.

The development of eco-industrial parks in which waste from one company becomes feedstock for another with the purpose of closing the cycle is one practical way of implementing the two metabolisms.

Modular construction allows modernization of goods by allowing replacement of components either worn out or obsolete. Components from used products could be reused in manufacturing of new products. The life of product components need to be synchronised. Repair services must be built up. Collaboration among consumers, producers and

government is required for the change. In general, ecological engineering reinforces the "sustaining" phase i.e. ensuring that the product or process has as long a life as possible in the market, the last step in the five stage innovation process identified by V. Jolly (The Economist, 1999).

The requirement of using Best Available Environment Technologies encourages the use of existing and end of the pipe technologies. The regulatory regime should be performance based rather than technology based. The practice of Ecological Engineering could make many environmental regulations obsolete.

Manufacturing activities have a higher R & D intensity than services, which are gaining share in the economy. There is a trend towards intensification of R & D in services. The sources and processes of technical change in services are poorly understood. It is therefore not clear that the growing share of services slows technical change down (OECD, 1997a).

Services that invested heavily in information and communications experienced strong productivity gains and job growth in the 1980's. Network interactions between suppliers, users and third parties are also important (OECD, 1997a).

Though firm capital budgeting decisions and cost-benefit analysis remain important decision aids, they must be supplemented by life cycle analysis, risk assessment, and ecological valuation (US Global Environment and Technology Foundation, 1995).

There is little prospect that clean technologies will be adopted through voluntary actions alone. The diffusion is slow and patchy due to organisational and market failures, especially in the small business sector (Ekins, 1998). Externalising is still the baseline for profitability. Only government intervention in the competitive rules may change the situation and give a competitive advantage to the most efficient firm.

Ecological Engineering certainly offers a way to integrate the environmental dimension in an innovation system. By mimicking natural processes and safeguarding the quality of products from cradle to cradle, it ensures the durability of natural capital; it defines the meaning of sustainable yield in the deepest ecological sense (mimicking natural processes rather than assigning constancy to them) and extends this sustainable yield perspective to non-renewable resources (Holling, 1995).

---

[10] See supra p. 5

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page

Author - Industry Canada

Publication Date - 2000-03-29

7. Human Capital: Connectedness, Productivity and Sustainable Development

In order to explain economic growth, one has to pay more attention to less tangible forms of capital accumulation than physical capital. These less tangible forms of capital include R & D, training and various forms of organisation. They take the form of investment in human capital which generates skills and innovation. Most innovations are continuous and cumulative by nature and are mainly combinations of techniques rather than completely novel products or novel processes or systems. This means that the learning process is localized and cumulative.

According to a recent poll, 40% of Canadians believe that improving productivity requires a national learning strategy to assist workers in improving knowledge and skills versus 37% in favour of tax cuts and 20% in favour of a technology strategy which would speed up diffusion of latest high tech processes and equipment.[11]

Technology is often singled out as the culprit for job losses as well as for the widening wage gap between skilled and unskilled labour.[12] Technological progress is an engine for job creation as higher wages and profits resulting from technology induced productivity gains and lower prices lead to increased demand for new products from existing as well as new industries. The effect of technical change on employment has long been characterized as "creative destruction": with innovation, some jobs disappear, while others are created. However, factors such as firm-specific skills and the trust and team spirit arising form repeated interactions within a stable relationship mean that a certain level of rigidity is inherent to labour markets. Consideration must be given to whether new jobs in one area complement or replace those in others, and whether the overall quality of jobs improves. On the supply side, education and training policies designed to upgrade skills may help reduce unemployment and the pressure for increased wage inequalities as well as improve the pace of innovation and diffusion. On the demand side, policies that target start-ups and growth of small and medium size enterprises are important for job creation.

While high-productivity industries and firms tend to record above-average productivity and employment growth, technology has brought a sharp increase in the demand for skilled labour while the situation has markedly deteriorated for unskilled labour. Small innovative firms and especially new technology-based firms are a main engine of growth and job creation.

Minimum qualifications requirements have risen, emphasising continuous learning and incentives to upgrade skills and improve performance. To date, high performance workplaces have been adopted by a minority of firms, mainly large manufacturing and service firms that face strong competition. To increase the benefits and reduce the costs associated with workplace innovation requires a systemic policy approach encompassing industry and technology, education, employment and industrial relations. Investments in intangibles are a necessary part of workplace innovation, but intangibles are inadequately measured and researched. Qualifications of workers have risen within occupations and industries, and qualifications of workers have risen faster in those sectors and occupations with the most growth in employment. Overall, the shift towards adoption of high-performance workplaces and other workplace innovations has been accomplished in many countries by increases in the share of non-standard, part-time, short-term, contract employment and self-employment. This is due in part to increases in outsourcing and firms' tendency to focus on their core activities. A set of "core" employees with more responsibility, higher skills and greater rewards for performance has developed in parallel with the growth of peripheral contingent workers, and, in some countries, increasing unemployment owing to inefficient job generations mechanisms. This suggests that security of employment and earnings depends increasingly on workers' qualifications and access to training, yet training practices in enterprises, and training opportunities outside enterprises, are very diverse. Furthermore, the trend towards "individualisation", which ranges from increased individual responsibility in the workplace, to individualised pay settings and contracting arrangements (often involving contingent employment) may increase a sense of insecurity. These developments leave little room for collective approaches traditionally adopted by trade unions. Trade unions have yet to develop alternative approaches that serve the new needs of current and potential members. Overall, strengthening the cooperative relationships between employers and employees depends on broadening the industrial relations agenda to address work organisation, business strategies, enterprise competitiveness and employee welfare, and on enhancing the capacity to address such issues at the appropriate level.

One needs to:

1) improve the basic skills of school leavers to ensure that fewer young persons lack vocational qualifications and the foundation for further learning;

2) reinforce and expand the ability of formal education systems to met the learning needs of adults, particularly those with low levels of initial qualification, and improve the framework for investing in further education and training;

3) ensure that, as higher education enrolments grow, the balance between academic and scientific and technical studies is appropriate in view of labour market conditions and the directions in which qualification requirements are evolving.

Governments retain much of the direct responsibility for ensuring that individuals have the basic generic and core skills needed for employment and the foundation for lifelong learning. This requires quality in basic education, by ensuring that individuals are well informed about educational choices, and by setting appropriate outcome standards. Schools should be encouraged to have stronger links with employers, including temporary employment

agencies, insofar as they monitor qualifications requirements and are in the position to help the young to try different jobs. In meeting the needs of those most at risk, schools need flexibility in deciding how to meet such standards as well as flexible mechanisms for assessing and recognising outcomes. Where this involves a change in their tasks, teachers need to be properly equipped.

Beyond basic schooling and providing poorly qualified adults with basic skills, the government's principal focus should be on infrastructure for providing information, choice, and incentives for human resources development. This involves financing incentives, new approaches to measure learning, and reinforce job placement activities.

Financial accounting and reporting practices fail to recognize learning as long-run asset. There is a need for incentives in increasing teaching efficiency as well.

Intangible assets include technology, human capital, organisational flexibility, and a conception of the nature and boundaries of the firm that allows greater external network formation and concentration on core activities, marketing and software. Intangible assets when joined to organisational changes are linked to strong performance. However, the shift towards investment in human resources and intangibles that complement tangible assets has been slow and uneven across countries and sectors. The slow diffusion is due in part to constraints such as managerial resistance, skills shortages, and lack of specific know-how in introducing management practices. In particular, diffusion has been slowed by the difficulties enterprises and financial markets have had in defining, measuring, evaluating and, in the case of firms, managing intangible assets, partly owing to biases in the information and reporting systems of enterprises. While these systems provide ample information on traditional forms of investment, they under-report or distort information on human resources and other intangible assets. Thus, while the acquisition of new machinery is treated as investment, the acquisition of new skill to run the machinery is treated as cost, and, while the machinery is valued as an asset, the acquisition of new skills to run the machinery and the attendant reorganisation of work, and acquisition of other intangibles (technology, marketing ability, and software) are treated as costs and their value is invisible.

Connectedness

Connectedness reduces the need to travel and nano-technologies decrease the demand for material and energy and, therefore, is conducive to eco-efficiency and SD. Countries are trying to define overall policy frameworks for migration to a fully digital environment, offering enhanced audio-visual services as well as new multimedia and interactive services (such as home shopping, games and social and health services). Comprehensive frameworks are important because of the possibility that - irrespective of the number of channels - existing policies and market structures for content production and delivery could mean that many channels are in effect underutilised or of too poor quality to attract enough consumers to make investments profitable.

The electronic communications sector is responsible for the creation of many jobs. For example, since 1985, the US motion picture industry has created over 1/4 million jobs.

---

11. See Globe and Mail, March 16, 1999 (p. A6) referring to the same poll mentioned above

in footnote 3.

12. The balance of this section is entirely based on OECD, 1997b.

Author - Industry Canada

Publication Date - 2000-03-29

8. Social Capital and the Rules For the Productivity Game

Institutions are a form of capital, social capital (Loury, 1977; Coleman, 1988). At the microeconomic level, social capital may be viewed as a social network and associated norms which may improve the functioning of markets and the productivity of the community for the benefit of the members of the association (World Bank, 1997; Putnam, 1993; Coleman, 1988). At the macroeconomic level, social capital includes the political regime, the legal frameworks and the government's role in the organization of production in order to improve macroeconomic performance as well as market efficiency (North, 1990; Olson, 1982). Social capital, like natural and human capital, is at the same time an input and an amenity. As an input, it enhances the benefits of investments in other factors and, thereby, shares the "shift" feature of technology (World Bank, 1997). Social capital is a public good and suffers, therefore, from underinvestment. Examples of social capital are mutual credit (increase capital mobility) and insurance associations (spread risk), co-management (lower information costs), etc.

Societies in which trust and civic cooperation are strong, a component of social capital, have significant positive impact on productivity and provide stronger incentives to innovate and to accumulate physical capital. Trust and civic cooperation tend to affect human capital productivity especially. This is especially true for developed countries (Knack and Keefer, 1997). This is an argument in favour of using a covenant-like approach to the development of sustainable technologies.

To implement ecological engineering solutions, a shift from production responsibility to product liability is required. Sweden has an eco-cycle law (1993) which extends the manufacturer's liability to the total product life; it is directed at returning waste and scrap to nature in such a state as to make them absorbable by the natural cycle (Kuntze, 1998). Market place frameworks, laws and policies, being the rules of the game, are clearly part of social capital.

A growing proportion of businesses seek more flexible and innovative strategies and forms of work organisation in order to use new technologies efficiently.[13] The factors critical to the success of small innovative firms and especially technology-based firms are: business opportunities, an entrepreneurial culture, a supportive business and technical infrastructure, and the availability of and access to key resources, especially venture capital. Governments influence these factors in many ways. In addition to creating appropriate conditions for

business start-ups (e.g. simplification of administrative and legal procedures), they should ensure that the tax and regulatory environment does not discourage entrepeneurship.

The prerequisites for organisational change and greater investment in intangible assets, influence both the supply of and the demand for different categories of labour. Generally speaking, the prospects for broad-based technical progress are strengthened by social cohesion which tends to be associated with a higher average level and lower dispersion of education, more favourable conditions for trust and mutual learning. Conversely, technology policy can help improve social cohesion, particularly to the extent that it enables job creation and is associated with broad-based up skilling. Yet, "creative destruction" and greater flexibility unavoidably hurt some categories of workers in the short and medium run. Governments commonly seek to defend social cohesion at the expense of investment in human capital, risk taking and entrepreneurial activity. Policies aimed at enhanced technical progress and those maintaining social cohesion should be mutually reinforcing. Technical progress inevitably involve transition problems which need to be addressed in order to avoid undercutting political support for the required incentive structures and structural change.

The economic environment in which both government and firms operate is being fundamentally transformed by globalization, liberalisation and market deregulation. There are also important changes in macroeconomic conditions, including more stringent fiscal policies and evolving societal demands. The emergence of a knowledge-based economy is spurred by advances in information and communication technologies which facilitate the processing, circulation and accumulation of knowledge. Globalization of product markets and of investment strategies enlarges markets and thus raises returns to sunk investments such as R&D. Higher costs of R&D, due to growing sophistication of the requisite human and physical resources, increase the efficient scale of facilities and create economies of scope for research consortia. Governments play a role in shaping and developing technological infrastructure, in creating incentives for accumulating skills and to establish the general business environment. Because of population ageing and growing ecological awareness, technology is being asked to make a greater contribution to solving health care and environmental problems, areas which at the same time are becoming an important playground for new business and innovation. Conversely, certain technological advances raise ethical concerns as well as fears that accelerating technological development and growing income differences caused by disparate trends in knowledge accumulation will aggravate inequalities and social exclusion.

Firms need to operate within a reasonably complete set of institutions (e.g. appropriate conflict resolution procedures, accounting practices, corporate governance structures, and venture capital markets). If market and non-market institutions interact poorly, technological change will be slowed and/or its contribution to economic growth and welfare will be reduced e.g. through locking in inferior technological trajectories. Mismatches between different components of an innovation system are referred to a systemic "failure". In practice, mismatches can take several forms: market and non-market institutions may be missing, or weak, public sector institutions and markets may have conflicting incentive structures.

Governments need to intervene in the public goods area i.e. research infrastructure, education, standards and innovation-inducing regulatory frameworks. The remedy to market failures is to fund basic research and some R & D and to allow firms to appropriate more of

their research (intellectual property rights, collaborative R & D).

Remedies to systemic failures are fostering innovative behaviour and allowing the development of new growth areas (financial markets supportive to new technology-based firms and regulatory reform that paves the way for demand of new services, accumulation of human capital, managerial and organisational capabilities). Governments are trying to increase the compatibility of support instruments with the market mechanism and develop mission oriented programs to meet new societal demand.

New organisational innovations are termed high-performance workplaces. The high performance workplace is a loosely defined model based on high skill, high trust, "intrapreneurship"(turn a company into a "hundred-headed brain"), "moonlighting" (individual working on pet ideas) and even "skunk-works"(violating company rules) (The Economist, 1999). Jobs are more complex and involve more tasks and greater interdependence and communication with other workers, with suppliers, and with customers. Hierarchies are reduced as responsibilities are shifted down to operators and sometimes to autonomous work teams with enterprise, or out to supplier firms. Minimum qualifications requirements rise, and greater emphasis is put on continuous learning and training, coupled with stronger incentives for upgrading skills and improving performance. By the mid-1990's, it is estimated that this model has been adopted by about a quarter of all enterprises in the OECD area, particularly large ones. It has been widely adopted in manufacturing firms faced with high levels of international competition. Assembly industries, notably automobile producers, typify these changes, placing the accent on quality and flexibility, reducing capital use, and shifting from vertical integration to horizontal supply arrangements. In services, change has been most pronounced in financial services and other trade and business services facing mounting competition. These trends are also reflected in aggregate trends towards downsizing, smaller and more sophisticated production units, outsourcing, subcontracting, and the formation of networks among firms.

Above all, "a risk-taking, achievement-oriented culture must be there to start with. So must a financial structure that hands out big rewards for success but not big punishments for failure. Good bankruptcy laws- those that allow entrepreneur to learn from their mistakes and try again - are essential. And clearly all the supporting infrastructure- the microchip design boutiques, the venture capital, the marketing services- has to be in place as well."(The Economist, Survey on Innovation in Industry, 1999, p.28)

---

13. The balance of this section is based on OECD, 1997b.

Author - Industry Canada
Publication Date - 2000-03-29

9. Win-Win Solutions

"No-Regrets" or "Double-Dividend" or still "win-win" solutions are zero-cost options. They increase at the same time X-efficiency while protecting equity and decreasing pollution (IPCC, 1996). No regret measures are measures which are worth implementing no matter which event actually happens whenever consequences are uncertain.

The existence of a no-regrets potential implies:

(1) that markets and institutions do not behave perfectly because of market failures (lack of information, distorted price signals, lack of competition, non-greenhouse externalities, capital market imperfections, etc.) and/or institutional failures (inadequate regulation, inadequate property rights, distortion-inducing fiscal systems, etc.);

(2) that it is possible to identify policies that have the ability to correct these market and institutional failures without implementation costs larger than the benefits gained;

(3) that a policy decision is made to eliminate selectively those failures that give rise to pollution (IPCC, 1996, p.272).

In the US, output growth in natural resources industries (coal, copper, logging, petroleum) had stagnated in the 1970's. Coal and logging output expanded considerably thereafter. Petroleum output kept decreasing while copper output first deteriorated and then made a strong recovery. Output prices had increased during the 70's. Except for logs, prices fell thereafter, following individually different and non-monotonic paths; for logging, prices actually increased. Covering the period 1945-1995, labour productivity was generally stagnant or actually decreased until the mid-seventies. This was not due to long-run scarcity but rather to high prices. These attracted inefficient producers and gave the opportunity to phase in environmental regulations. After the seventies, output prices decreased forcing restructuring and technological innovations in the respective industries. In the coal industry, labour productivity more than doubled between 1970 and 1994 and grew at an average of

2.4% per annum. Labour productivity was stronger in the copper industry where it grew at 3.7% per annum. In petroleum, it decreased reflecting the exhaustion of US reserves and, in forestry, it went up at 1.4% per year. The trends are similar to the ones in manufacturing. In the coal industry, productivity was boasted by the adoption of labour saving technologies. In the petroleum and copper sectors, productivity was boasted by closing down the least efficient mines i.e. by reducing the extensive margin of extraction. In the logging industry, a similar process played a role but tree plantations and biotechnology played a role as well (Parry, 1997a).

Pollution prevention rather than end of the pipe solutions seems to be a win-win solution for firms to go. It may require redesigning products and processes and modification of supply and demand relationships. There is a feeling, however, that firms do not take advantage of these win-win solutions and, therefore, that regulation is needed (see supra p.11). Case-studies have revealed two difficulties: in two cases, pollution prevention investments did not survive the firm's capital budgeting process; in a third case, difficulties resulted from a pollution prevention product being sold to large group of customers who themselves have to decide whether or not to adopt pollution prevention behaviour. A problem is, of course, to find out whether firms have the means (e.g. green accounting) to assess environmental benefits. However, there seems to be indications in the case-studies that these benefits are taken into account qualitatively. Lack of regulatory flexibility, of more holistic performance-based (instead of technology-forcing for individual pollutants) regulation, and of allowing for technological experimentation and longer time-horizons for compliance are barriers to pollution prevention and to technological and environmental information innovation (Boyd, 1998). Even though published empirical evidence is mixed, EPA has documented several favourable and unfavourable cases to the existence of win-win solutions (see supra, p. 18; Boyd, 1998, footnote 6 for references).

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page

Author - Industry Canada

Publication Date - 2000-03-29

10. Conclusions

Sustainable Development (SD) and Neo-classical Economics (NCE) provide different but overlapping perspectives on how society may address economic, environmental and social challenges. While conclusions on the areas of convergence and divergence are possible, it is important to note that the conceptual development of SD is in a relatively early stage compared to that of NCE.

Areas of convergence and divergence between NCE and SD approaches to the four forms of capital, to innovation, to connectedness and high performance workplaces are represented on figure 3. Clearly, efficiency is the dominant value in Neo-classical Economics while equity dominates SD. This is particularly true for intergenerational issues. However, equity issues are not completely absent from NCE but are kept separate from efficiency issues. In SD, equity and efficiency are intertwined but equity dominates. Therefore, when Neo-classical-based policy is concerned about equity, matters such as fairness in market place, economic development of groups/regions, community economic development, the two agenda overlap as long as short-run equity gains are not at the expense of future generations.

Our actual economies are not Pareto-optimal. Therefore, there is room for increased efficiency, for no-regrets solutions. While, to-day's Neo-classical economic agenda emphasizes deregulation in order to improve efficiency, SD focuses on win-win or no-regrets solutions which aim at increasing the scarcity of natural capital, thereby increasing economic efficiency jeopardized by pervasive environmental externalities and, at the same time, improving the way towards other societal goals such as higher employment, higher profits, etc.

Sustainable Development **Convergence** **Neo-Classical Economics**

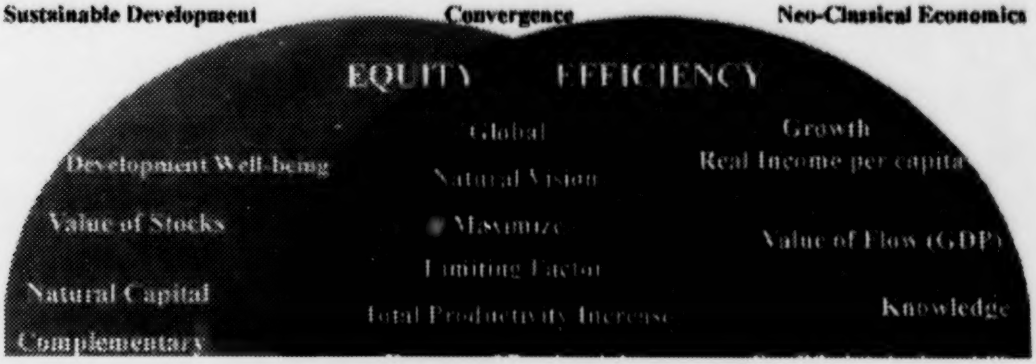


FIGURE 3: Areas of convergence and divergence between Sustainable Development and
Neo-Classical Economics

SD focuses on well-being and on Development while NCE focuses on real income per capita, on Growth. In other words, SD focuses directly on ends while NCE focuses more on means. Nonetheless, it is clear that while productivity growth may not necessarily increase well-being through income growth, it is capable of doing so.

Both recognize that the benefits of sustainability and of market performance must be global and systemic in character but in SD more so than in NCE.

While NCE attempts to maximize the value of the service of aggregate capital i.e. current and future GDP, SD focuses more on maximizing the value of aggregate capital and its components. Though, in theory, the two approaches should be equivalent, an emphasis on capital promotes a wide set of possible futures as part of well-being rather than their actual realizations. Moreover, while Neo-classical Economics is rather indifferent about the composition of GDP, SD makes perfectly clear that its material and energy content should be as small as possible (dematerialization and eco-efficiency).

Both NCE and SD emphasize maximizing total factor productivity as a necessary condition for well-being. However, the obstacles to this maximization are identified differently. Neo-classical economics considers that knowledge is the truly scarce factor while SD assigns this role to natural capital. Moreover, NCE tends to emphasize the substitutability of factors of production while SD tends to emphasize their complementarity. Therefore, increasing natural capital productivity automatically increases total factor productivity in SD.

In Neo-classical Economics, the horizon is essentially dictated by the discount rate. In SD, longer horizons are dictated by ecological considerations. While SD does not reject the discount rate, it subordinates and limits it to its efficiency function. SD maximizes the productivity of capital through eco-efficiency, natural resource saving technical progress and substitution of renewable resources to non-renewable ones. Neo-classical Economics tends to focus on the productivity of human resources instead and, through the Schumpeterian approach to endogenous growth, on innovations embodied in human resources.

While NCE emphasizes products, SD emphasizes services from products treated as assets.

NCE emphasizes benefit/cost analysis as the main tool for decision-making. SD tends to emphasize the uncertainty and potential irreversibility that surround decisions involving natural capital. Accordingly, SD tends to emphasize the value of investing in conservation as insurance against irreversible losses of unique assets (precautionary principle).

Though the value systems of NCE and SD are rather far apart, through the emphasis on the importance of social capital and innovations directed at human resources rather than at physical capital, there is an overlap between the two. Except for global environmental problems plagued with open-access resources management problems, the quality of local environments has tended to increase over the last 25 years. The multiplication of services which are not intensive in natural capital is an encouraging trend as well. The systematic remediation to the absence of market-based scarcity indicators for natural capital such as eco-taxation, and the absence of incentives to adopt ecological engineering approaches still require attention from policy.

For business to implement SD, it should strive to change from a culture of simply coping (damage control) and of compliance (end of the pipe solutions) for one of comprehensive environmental management (eco-efficiency) and pursuit of sustainable development through integration of economic, environmental, social and financial dimensions. Tools for this integration are clear objectives, indicators against which to measure performance, life cycle management and scenario building with backcasting (Commissioner Report, 1998).

In point of fact, NCE is opening more and more to ecological considerations. By its emphasis on human resources and its adoption of a Schumpeterian approach to innovation - knowledge and organization (social capital), growth tends to become more service-oriented and less intensive in natural resources. What remains to be done to complete the convergence between Neo-classical Economics and SD is to shift the emphasis from labour productivity to natural capital productivity, from too narrow benefit-cost or capital-budgeting analysis to one which encompasses concerns for irreversibilities, information, and non-price indicators of environmental scarcity. The latter open the door to a bright future for the information technologies. An emphasis on social capital necessarily requires a greater and more systemic role for governments than acknowledged by a narrow market perspective. Markets bring efficiency but do not function without an institutional framework and trust i.e. the threads which hold social capital together. Finally, there are no institutions and there is no trust without equity or fairness.

Author - Industry Canada

Publication Date - 2000-03-31

References

Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, MIT Press.

Archibugi, D. And J. Michie, 1998: Technical Change, Growth and Trade: New Departures in Institutional Economics, *Journal of Economic Surveys*, 12(3), 313-32.

Arrow, K.J., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B. Janson, S. Levin, K. Goran-Mäler, C. Perrings, D. Pimentel (1995), Economic Growth, Carrying Capacity, and the Environment, *Science*, 268, 520-21.

Ayres, R.U., (1994), On Economic Disequilibrium and Free Lunch, *Environmental and Resource Economics*, 4(5), 435-454.

Ayres, R.U. and P.M. Weaver (Eds.), (1998), *Eco-restructuring: Implications for Sustainable Development*, United-Nations University Press.

Barbier, E.B., A. Markandya and D.W. Pearce (1990), Environmental Sustainability and Cost-Benefit Analysis, *Environmental and Planning* A, 22(9), 1259-66.

Barro, R.J. and X. Sala-I-Martin (1995), *Economic Growth*, McGraw-Hill.

Beckerman, W.(1993), Sustainable Development: Is It a Useful Concept?, *Environmental Values*, 3( ), 131-139.

Boskin, M. And L. J. Lau (1992), Capital, Technology, and Economic Growth, in N. Rosenberg, R. Landau and D. Mowery (Ed.), *Technology and the Wealth of Nations*, Stanford University Press.

Bossel, H. (1998), *Earth at the Crossroads*; Paths to a Sustainable Future, Cambridge University Press.

Boyd, J. (1998), Searching for the Profit in Pollution Prevention: *Case Studies in the Corporate Evaluation of Environmental Opportunities*, DP 98-30, Resources for the Future, http://www.rff.org.

Bromley, D.W. (1989), Entitlements, Missing Markets, and Environmental Uncertainty, *Journal of Environmental Economics and Management*, 17( ), 181-94.

Ciriacy-Wantrup, S.V. (1952), *Resource Conservation: Economics and Policies*, Berkeley: University of California Division of Agriculture.

CSLS: Centre for the Study of Living Standards (1998), *Productivity: Key to Economic Success*, March, http://www csls.ca.

Coleman, J., 1988: Social Capital in the Creation of Human Capital, *American Journal of Sociology*, 94(Supplement), S95-S120.

Commissioner of the Environment and Sustainable Development (1998), *Report*, c.5 Expanding Horizons - A Strategic Approach to Sustainable Development, Ministry of Public Works and Government Services Canada.

Common, M. And C. Perrings (1992), Towards an Ecological Economics of Sustainability, *Ecological Economics*, 6(1), 7-34.

Conference Board of Canada (1996), *Voluntary Initiatives in the Energy Sector*.

Crabbé, P. (1997), *Sustainable Development: Concepts, Measures, Market and Policy Failures at the Open Economy, Industry and Firm Levels, Industry Canada*, Occasional Paper Number 16.

Daly, H. (1996), *Beyond Growth*, Beacon Press.

Daly, H.(1998), Reconciling Internal and External Policies for Sustainable Development, c.2 in A.K. Dragun and K. M. Jacobson, Eds., **Sustainability and Global Economic Policy**, E. Elgar.

Dasgupta, P. and G. Heal (1979), *The Economic Theory of Exhaustible Resources*, Cambridge University Press.

de Jongh, P.E. (1998), The Policy Concept Behind the Dutch National Environmental Policy Plans, part 3 in Meyer-Krahmer et al.

Dosi, G., (1988), Sources, Procedures, and Microeconomic Effects of Innovation, *Journal of Economic Literature*, 26( ), 1120-1171.

Ekins, P. (1998), Can a Market Economy Produce Industrial Innovations that Lead to Environmental Sustainability?, part 1 in Meyer-Krahmer et al.

Farmer, M.C. and A. Randall (1998), The Rationality of a Safe Minimum Standard, *Land Economics*, 74(3), 287-302.

Faucheux, S. (1997), Technological Change, Ecological Sustainability and Industrial

Competitiveness, in A.K. Dragun and K.M. Jacobson (Eds.), *Sustainability and Global Environmental Policy*, E. Elgar.

Faucheux, S. and I. Nicolaï (1998), Environmental Technological Change and Governance in Sustainable Development Policy, *Ecological Economics*, 27(3), 243-56.

Georgescu-Roegen, N. (1979), Energy Analysis and Energy Valuation, *Southern Economic Journal*, 45( ), 1023-1058.

Goldemberg, J., (1996), *Energy, Environment and Development*, Earthscan.

Golding, I. and L.A. Winters (Ed.) (1995a), *The Economics of Sustainable Development*, Cambridge University Press.

Golding, I. and L.A. Winters (1995b), E*conomic Policies for Sustainable Development*, c.1 in Golding, I. and and L.A. Winters, (Ed..), 1-17.

Hamilton, K. and G. Cameron (1994), Simulating the Distributional Effects of a Canadian Carbon Tax, *Canadian Public Policy*, 20(4),

Hawken, P. (1995), Taking the Natural Step, Context, 41, 36-38.

Holling, C.S. et al., Biodiversity in the Functioning of Ecosystems: An Ecological Synthesis in C. Perrings et al., Biodiversity Loss: Economic and Ecological Issues, Cambridge University Press 1995, 44-83.

Howarth, R. B.(1998), Sustainability as Opportunity, *Land Economics*, 73(4), 569-79.

IC: Industry Canada (1998), *Making a Difference*: Our Priorities for 1998-9, Industry Canada.

IC: Industry Canada (1997), *Sustainable Development Strategy*, Industry Canada.

IPCC: Intergovernmental Panel on Climate Change, (1996), *Climate Change* 1995; *Economic and Social Dimensions of Climate Change*, Cambridge University Press 1996.

IPCC: Intergovernmental Panel on Climate Change, (1999), *Special Report on Technology Transfers*, mimeo.

Jaffe, A., S. Peterson, P. Portney and R. Stavins (1995), Environmental Regulation and the Competitiveness of US Manufacturing: What Does the Evidence Tell Us?, *Journal of Economic Literature*, 33( ), 132-163.

Knack, S. And P. Keefer (1997), Does Social Capital have an Economic Payoff: A Cross Country Investigation, *Quarterly Journal of Economics*, CXII(4), 1251-88.

Kuntze, U. (1998), Research and Technology Politics and Sustainable Development - the Situation in the USA, Japan, Sweden and the Netherlands, Annex in Meyer-Krahmer et al..

Kuntze, U., F. Meyer-Krahmer and R. Waltz (1998), Innovation and Sustainable Development - Lessons for Innovation Policies?, part 1 in Meyer-Krahmer *et al.*

Lahaye, N. And D. Llerena, (1996), Technology and Sustainability: an Organisational and Institutional Change, in S. Faucheux, D. Pearce and J. Proops (Ed.), *Models of Sustainable Development*, E. Elgar, 205-30.

Lamprecht, J.L.(1997), *ISO 14,000*, American Management Association.

Loury, G. (1977), A Dynamic Theory of Racial Income Differential, in P.A. Wallace and A. Le Mund (eds), *Women, Minorities and Employment Discrimination*, Lexington Books.

McDonough, W. and M. Braungart (1998), The NEXT Industrial Revolution, *The Atlantic Monthly*, October, http://www2.the atlantic.com/issues/98oct/industry.htm.

Meyer-Krahmer, F. (Ed.) (1998), *Innovation and Sustainable Development*, Springer Verlag.

Mondello, G.(Ed.) (1998), *Principe de précaution et industrie*, L'Harmattan.

Newell, R.G. (1997), *Environmental Policy and Technological Change: The Effects of Economic Incentives and Direct Regulation on Energy-Saving Innovation*, PhD thesis, Harvard University. Available at http://www.rff.org.

North, D., 1990: *Institutions, Institutional Change, and Economic Performance*, Cambridge University Press.

Norton, B.G. and M.A. Toman (1997), Sustainability: Ecological and Economic Perspectives, *Land Economics*, 73(4), 553-68.

OECD (1997a), *Environmental Taxes and Green Tax Reform*, Council at Ministerial Level, 26-27 May, http://www.oecd.org//sge/council/ministerial/papers/engcmin/2

OECD (1997b), *Technology, Productivity and Job Creation* - Towards Best Policy Practice, Interim Report, Council at Ministerial Level 26-27 May, http://www.oecd/org//sge/council/ministerial/papers/ .

OECD (1997c), *Eco-Labelling: Actual Effects of Selected programs*, GD(97) 105, http://www.oecd.org.

OECD (1997d), *Guiding the Transition to Sustainable Development: A Critical Role for the OECD*, Report of the High-Level Advisory Group on the Environment to the Secretary-General of the OECD, http://www.oecde.org/subject/sustdev/hlage.htm.

OECD (1998), *OECD Work on Sustainable Development*, http://www.oecd.org/ subject/ sustdev/oecdwork.htm.

Olson, M., 1982: *The Rise and Decline of Nations: Economic Growth, Stagflation, and Social Rigidities*, Yale University Press.

Ormola, E. (1998), The Role of RTD Policy and the Adequate Policy Mix - Comprehensive Policy Approaches and Problems Implementation, part 3 in Meyer-Krahmer et al.

Osberg, L. and A. Sharpe (1999), *An Index of Economic Well-Being for Canada and the United-States*, Paper presented at the American Economic Association, New-York, http://www.csls.ca.

Page, T. (1983), Intergenerational Justice as Opportunity, in D. MacLean, and P.G. Brown (Eds), *Energy and the Future*, Rowman and Littlefield.

Page, T. (1998), On the Problem of Achieving Efficiency and Equity, Intergenerationnally, *Land Economics*, 73(4), 580-96.

Palmer, K., W.E. Oates and P.R. Portney, 1995: Tightening Environmental Standards: the Benefit-cost or the No-cost Paradigm, *Journal of Economic Perspectives*, 33( ), 119-32.

Parry, I.W.H. (1997a)), *Productivity Trends in the Natural Resource Industries*, Resources for the Future, DP 97-39, http://www.rff.org.

Parry, I.W.H. (19987b), *Pollution Regulation and the Efficiency Gains from Technological Innovation*, Resources for the Future, DP 98-04, http://www.rff.org.

Porter, M.E. and C. Van der Linde, 1995: Toward a New Conception of the Environment-Competitiveness Relationship, Journal of Economic Perspectives, 33( ), 97-118.

Putnam, R., 1993: The Prosperous Community - Social Capital and Public Life, *American Prospect*, 13, 35-42.

Scott, M. (1995), *What Sustains Economic Development*, c. 4 in I. Goldin et al. (Ed.), 83-110.

Technical Committee on Business Taxation (1998), *Report*, Finance Canada.

The Economist (1999), *A Survey of Innovation in Industry*, February 20-26.

Toman, M., J. Pezzey and J. Krautkraemer (1995), Neoclassical Growth Theory and "Sustainability", c. 7 in D. Bromley (Ed.), The Handbook of Environmental Economics, Blackwell, 139-65.

US Executive Office of the President, President's Committee of Advisors on Science and Technology (1997), Letter to the President, January 7, http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/1797.html

US Global Environment and Technology Foundation (1995), *Technology for a Sustainable Future*, http://www.gnet.org/filecomponet/2472.html.

Wackernagel, M. and W. Rees, (1996), *Our Ecological Footprint*, New Society Publishers.

Wallace, D. (1995), *Environmental Policy and Industrial Innovation*, Royal Institute for International Affairs/Earthscan.

World Bank, (1997): *Expanding the Measure of Wealth*, World Bank.

Xepapadeas, A. and A. de Zeeuw, (1999): Environmental Policy and Competitiveness: the Porter Hypothesis and the Composition of Capital, *Journal of Environmental Economics and Management, 37(2), 165-182.*

Table of Contents

Help What's New Sitemap Feedback About Us Français Top of Page